High-fidelity impact analysis of composite structures using refined structural theories

HIGH-FIDELITY IMPACT ANALYSIS OF COMPOSITE STRUCTURES USING REFINED STRUCTURAL THEORIES

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Laminated composite materials are susceptible to damage and subsequent reduction in load carrying capacity under transverse loads, such as low-velocity impact. High-fidelity models are thus necessary to accurately predict the structural response due to impact. Various numerical techniques have been considered in the literature, for instance, using only cohesive zone modelling for both intra- and inter-laminar damage [1], or a combination of cohesive and continuum damage models [2]. Nevertheless, such numerical approaches lead to very high computational costs, making them infeasible for the analysis of large and complex composite structures [3]. The current work aims to address this issue by means of higher-order modelling via the use of the Carrera Unified Formulation (CUF).

CUF is a framework capable of developing advanced structural theories in a generalised manner [4]. Refined 1D and 2D elements are considered, where the use of expansion functions leads to an enrichment of the element kinematics, resulting in a 3D displacement field. Such an approach leads to 3D-like accuracy of the solution without a corresponding increase in the computational cost of the analysis. In the current work, expansion functions based on Lagrange polynomials are used to describe the beam cross-section and plate thickness, leading a purely displacement-based formulation. Such an approach results in a layer-wise modelling of the composite structure. This methodology has been used in previous works, such as the micromechanical progressive failure analysis of composites [5].

A non-linear explicit dynamics framework has been developed which utilises higher-order structural theories derived using CUF, to accurately capture transient phenomena that occur during impact. Contact between the bodies is modelled using node-to-surface contact with Lagrange multiplier constraints. Progressive damage in the composite structure is modelled using the continuum damage approach. Numerical experiments have been conducted to demonstrate the capability of the CUF-Explicit framework in the high-fidelity impact analysis of composite structures.

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